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QCD介质中喷注淬火的 --死角效应研究

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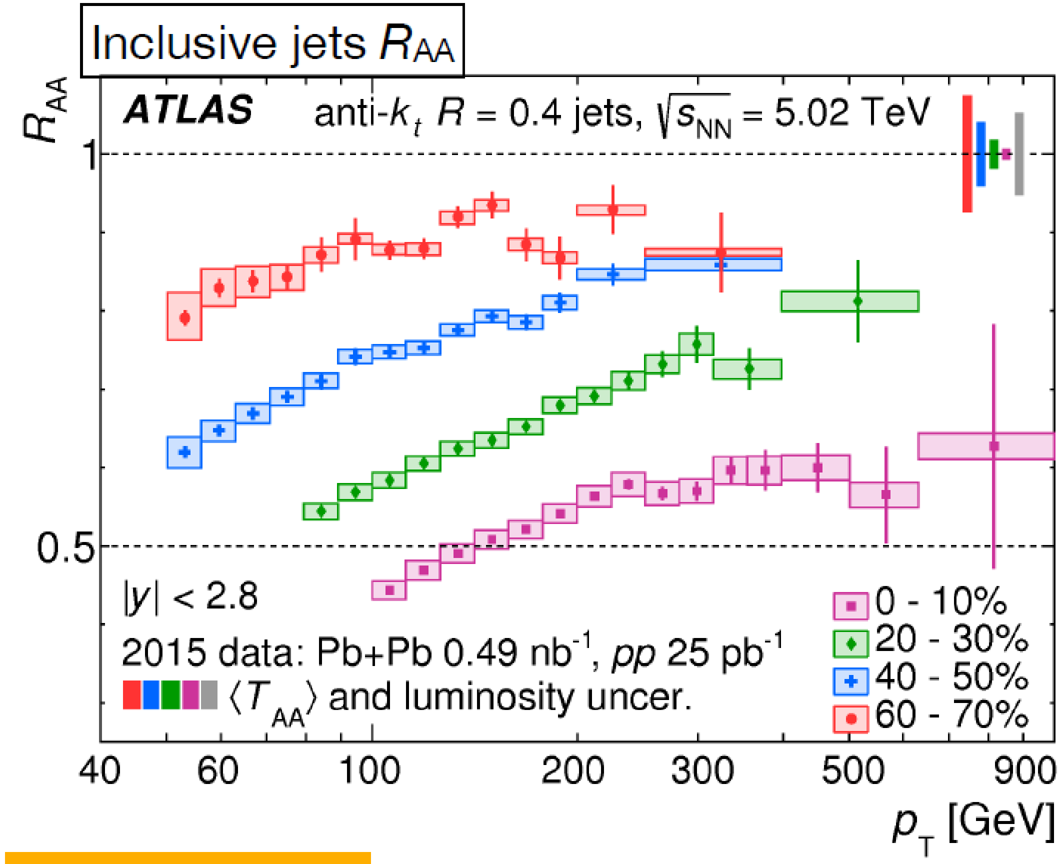
中国物理学会高能物理分会第十一届全国会员代表大会暨学术年会

Outline

- Introduction and Motivation
- The “Dead-Cone” Exposure in QCD
- The Splitting Angular in D meson tagged Jets in A+A
- “Dead-Cone” of Jet Quenching in A+A
- Outlook

Flavor and mass dependence in medium induced Energy loss

Jets are known to lose energy when going through the Quark-Gluon-Plasma



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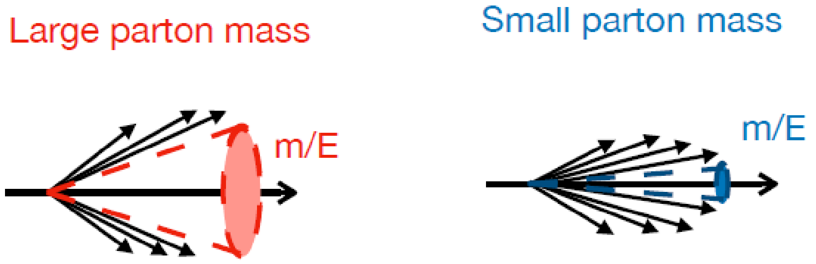
- Color-charge dependence

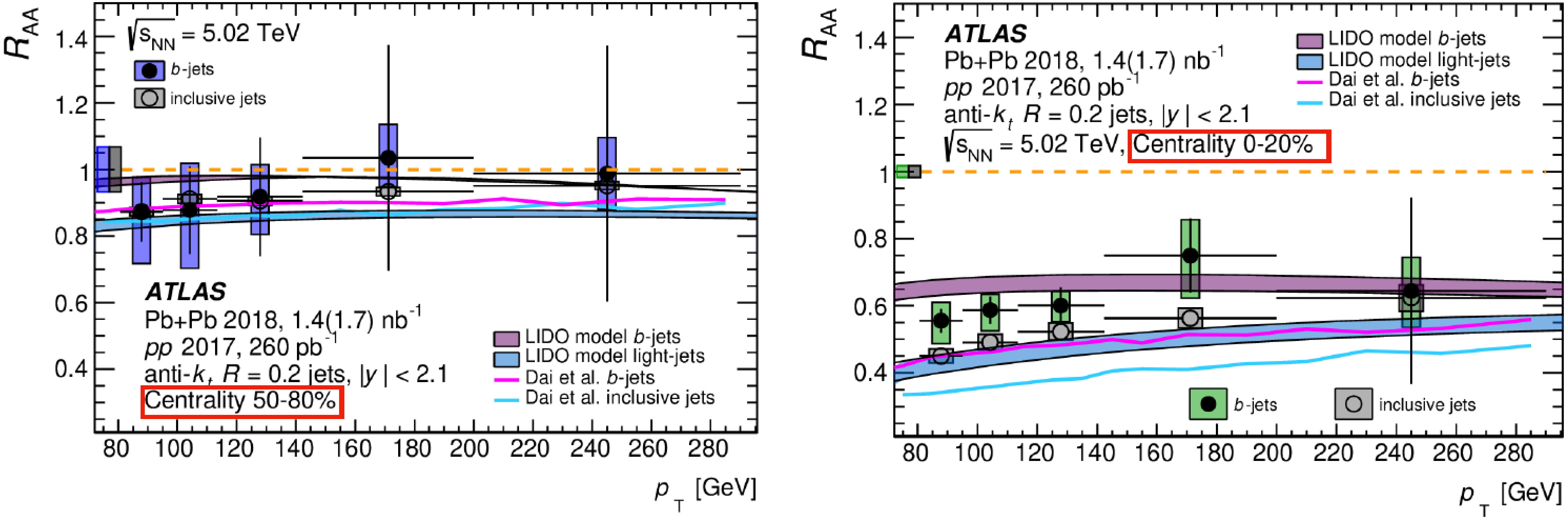
QCD suggest, gluons are more likely to radiate than quarks

- Mass dependence expected due to “dead-cone effect”



Radiation is suppressed in θ < m/E

b-jets vs inclusive jets in Pb+Pb collisions

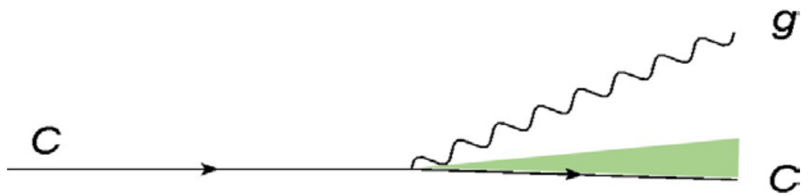


Nuclear modification factor, R_{AA}, measured for *b*-jets and inclusive jets:

WD, Sa Wang, Shan-Liang Zhang, Ben-Wei Zhang and Enke Wang CPC (2020)

- Similar suppression in peripheral collisions
- ***b*-jet found to be less suppressed than inclusive jets in central collisions**
- Both calculations capture the R_{AA} difference

Theoretical Definition of Dead-Cone



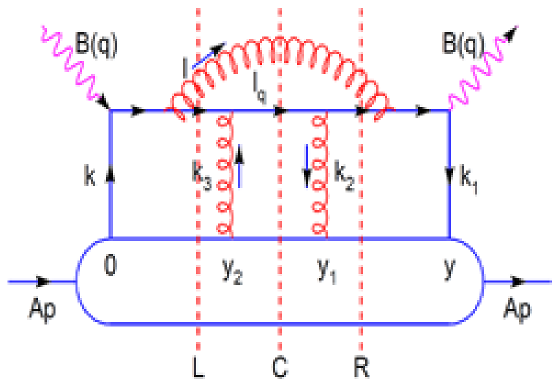
Gluon radiation , with dead-cone
Angle $\theta = m/E$

bremsstrahlung radiation spectrum off a light quark in vacuum:

$$dP_0 \simeq \frac{\alpha_s C_F}{\pi}\frac{d\omega}{\omega}\frac{dk_\perp^2}{k_\perp^2}$$

radiated gluon spectrum off a heavy quark in vacuum:

$$dP_{HQ} \simeq \frac{\alpha_s C_F}{\pi}\frac{d\omega}{\omega}\frac{k_\perp^2 dk_\perp^2}{(k_\perp^2+\omega^2\theta_0^2)^2} = dP_0\left(1+\frac{\theta_0^2}{\theta^2}\right)^2$$



In Medium:

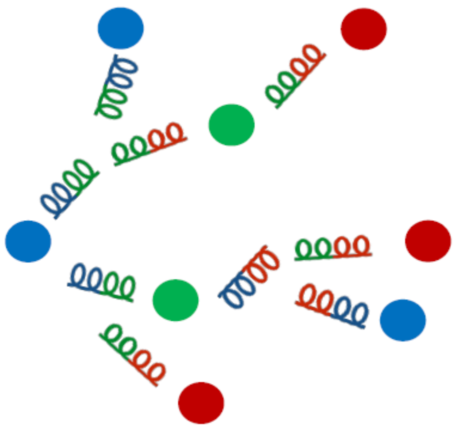
$$\frac{dN_g}{dx dk_\perp^2 dt} = \frac{2\alpha_s P(x)\hat{q}}{\pi k_\perp^4} Sin^2\left(\frac{t-t_i}{2\tau_f}\right)\left(\frac{k_\perp^2}{k_\perp^2+x^2M^2}\right)^4$$

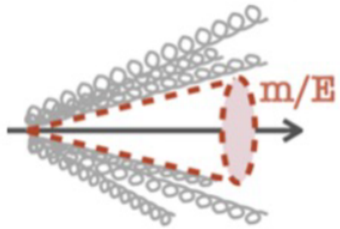
$$k_\perp = \omega\theta$$
$$\omega = xE$$

$$f_{Q/q} = \left(1+\frac{\theta_0^2}{\theta^2}\right)^{-4}$$

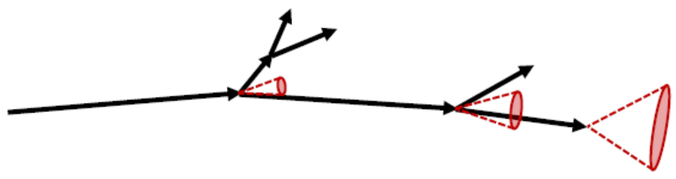
Dead-cone emerged in the parton shower

The pattern of the QCD parton shower exhibits a flavour dependence



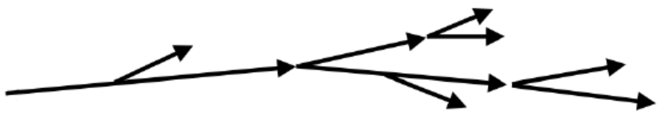


Angular region with size m_Q/E_Q within which emissions are supressed



Heavy-quark-initiated shower

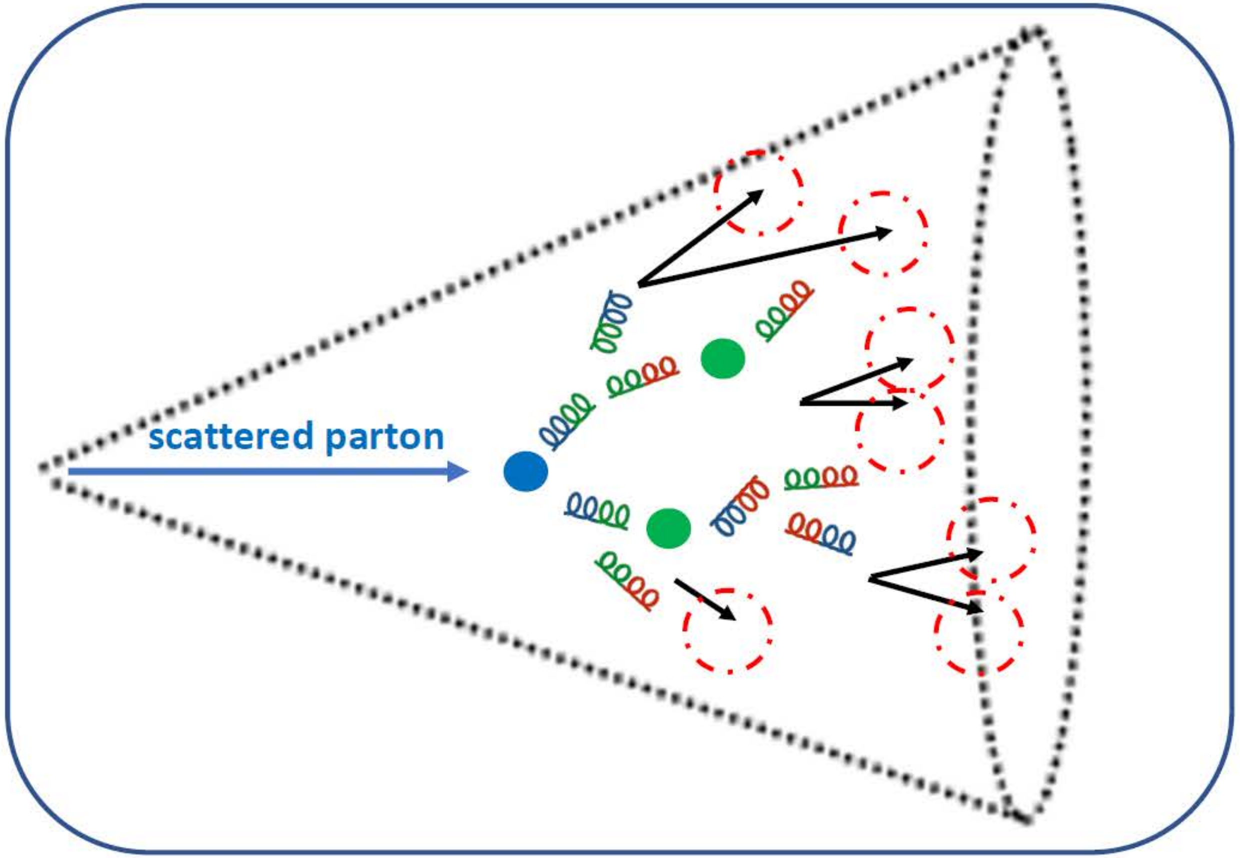
Suppression of small angle emissions
Harder fragmentation



Light-quark-initiated shower

No small angle emission limit
Softer fragmentation

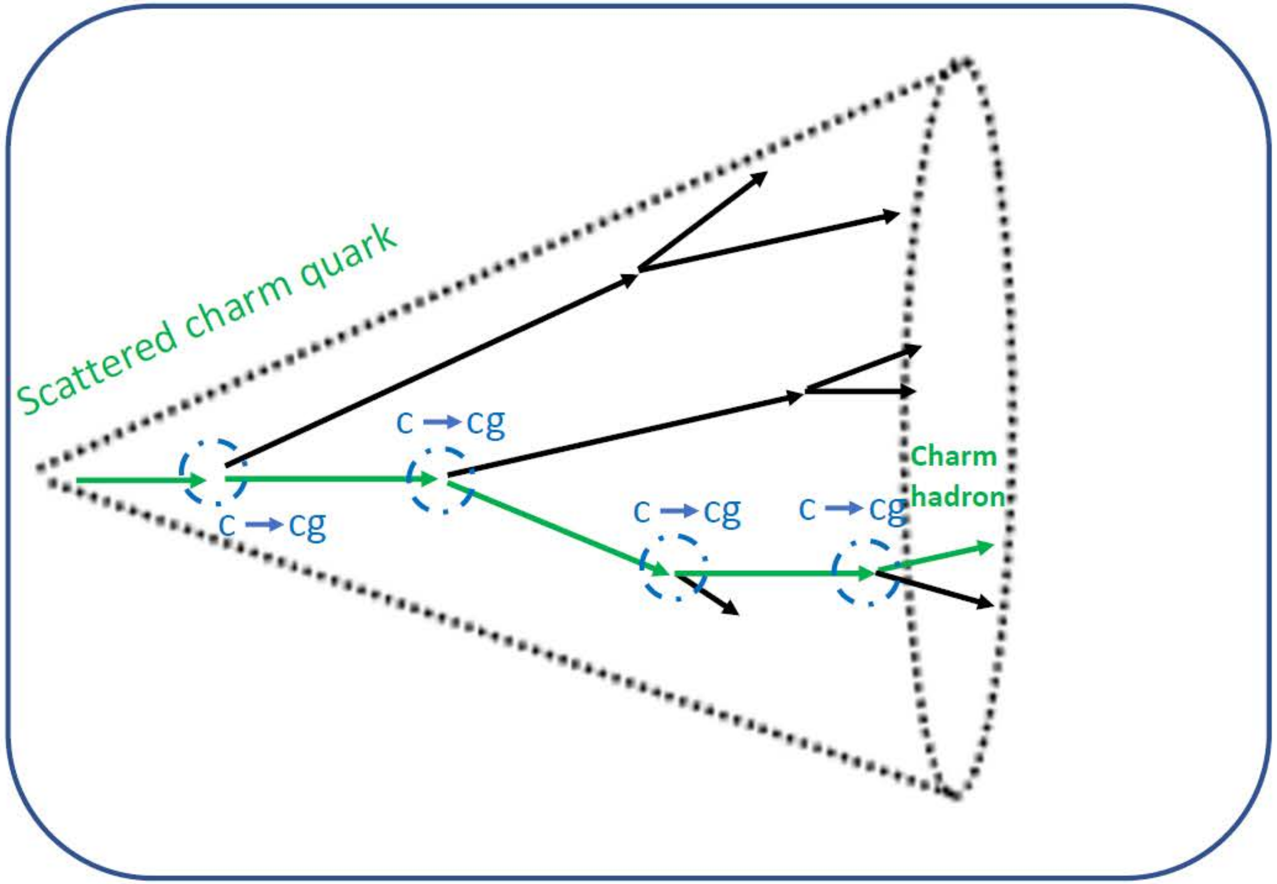
Capturing the parton shower



How can we experimentally reconstruct the initial hard scattering?

Jet algorithms identify and cluster hadrons originating from a single scattered parton

Heavy-flavour jets to isolate c->cg splittings

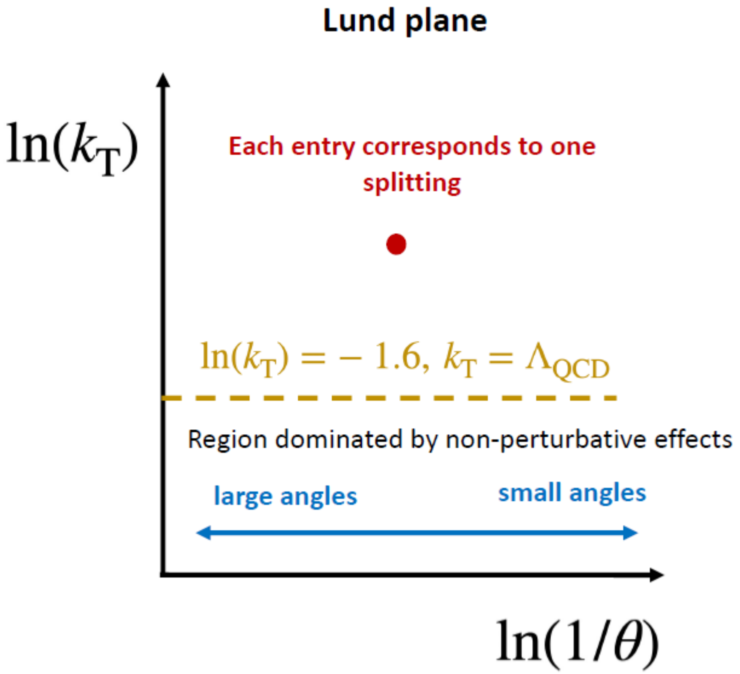


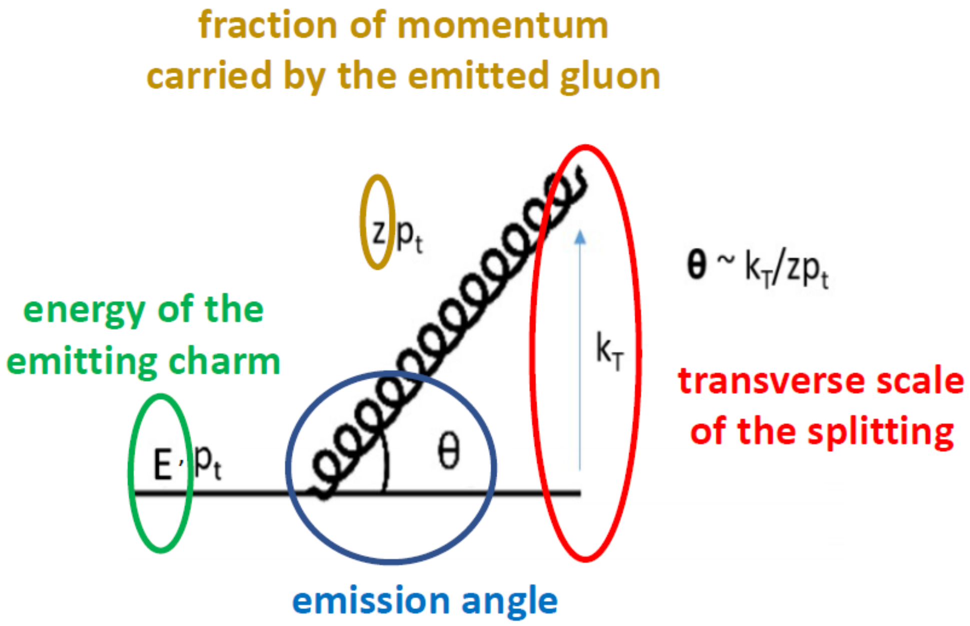
The charm quark flavour is conserved throughout the shower

Following the branch with the charm hadron is equivalent to following the charm quark

The kinematics of each c->cg splitting are dynamically updated

Reconstructed splitting kinematics



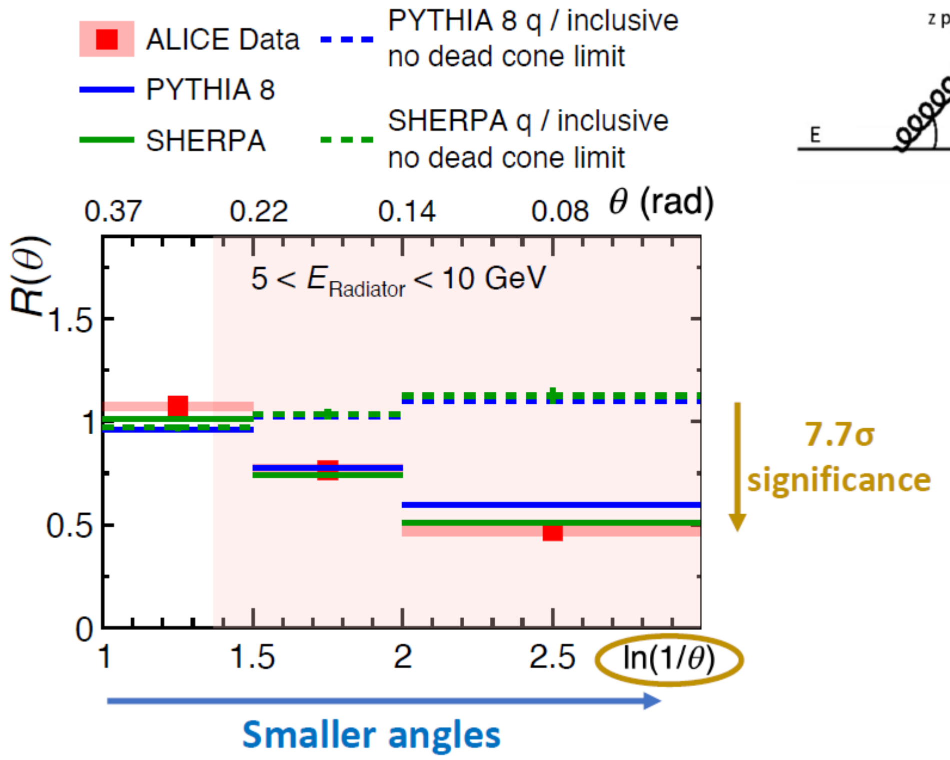


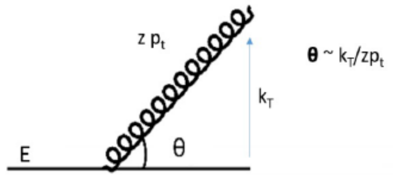
The splitting phase spaced can be mapped through 2D distributions called Lund planes

QCD phenomena such as the dead-cone effect and the running of the strong coupling manifest in the Lund plane emission densities

Uncovering the QCD dead cone

Nature 605 (2022) 440-446





The dead cone is uncovered through a direct measurement of the emission angle

Small angle emissions supressed for charm quarks compared to light quarks and gluons

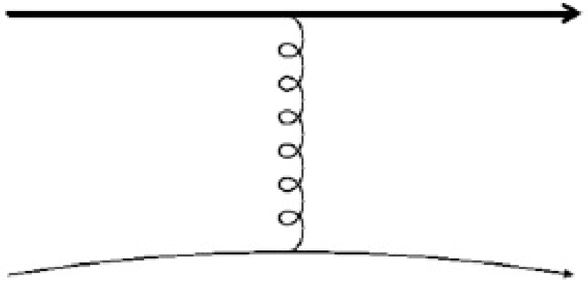
$$R(\theta) = \frac{1}{N^{\mathrm{D^0\,jets}}} \frac{\mathrm{d}n^{\mathrm{D^0\,jets}}}{\mathrm{d}\ln(1/\theta)} \Bigg/ \frac{1}{N^{\mathrm{inclusive\,jets}}} \frac{\mathrm{d}n^{\mathrm{inclusive\,jets}}}{\mathrm{d}\ln(1/\theta)} \Bigg|_{k_{\mathrm{T}}, E_{\mathrm{Radiator}}}$$

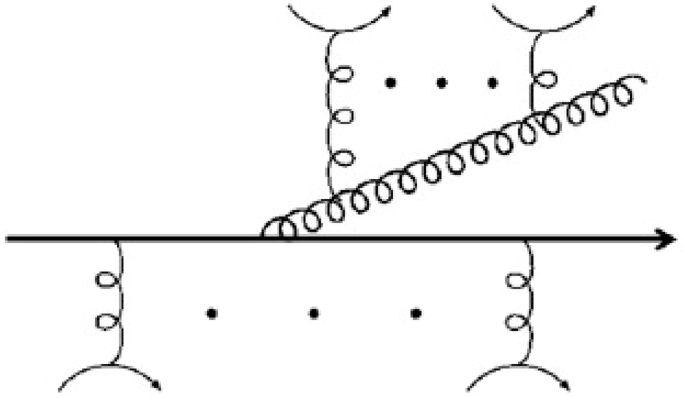
Compare the angular distribution of charm-quark emissions to those of light quarks and gluons

Jet energy loss in QCD Medium

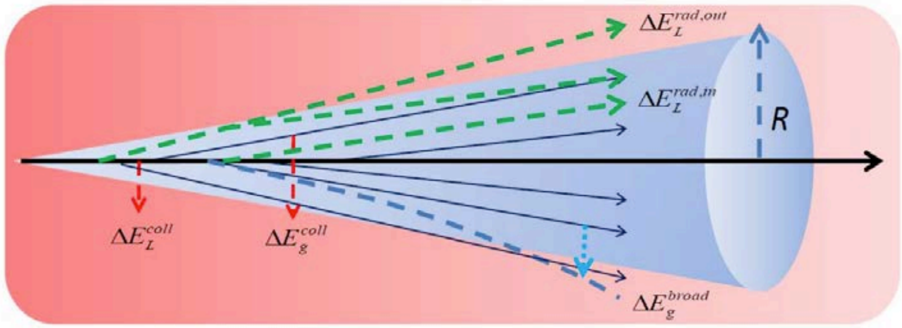
- SHELL Model used
  （Cross checked）
- Jet-medium interaction
- Reconstructed Jets Using Jet-finding algorithms

Collisional Energy Losses

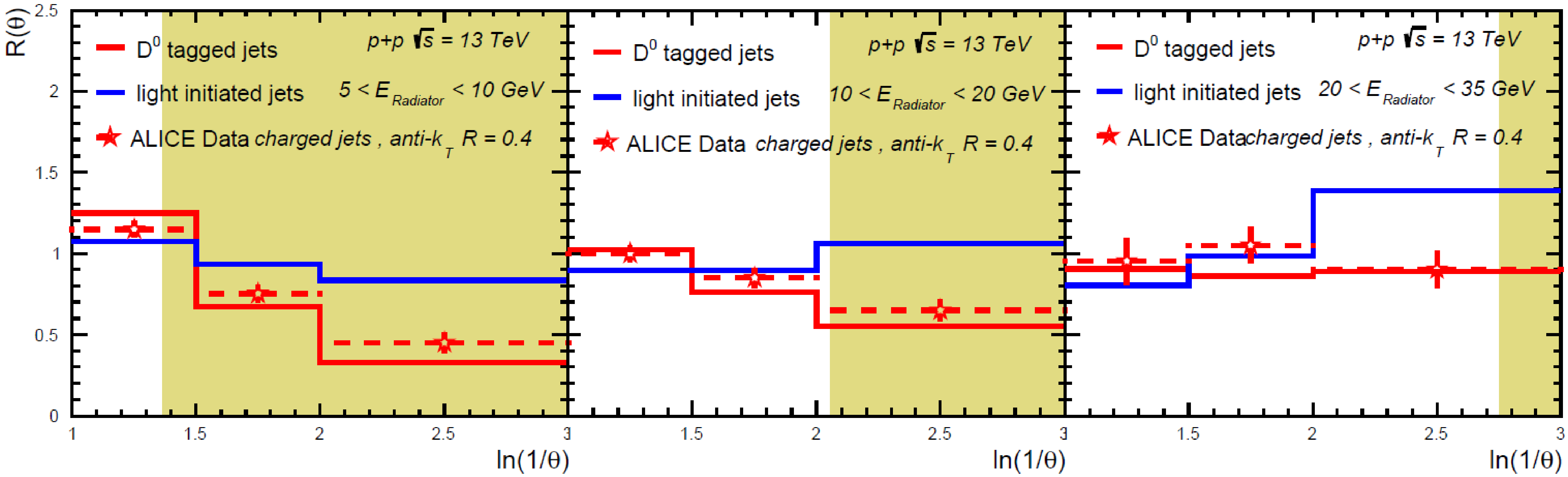




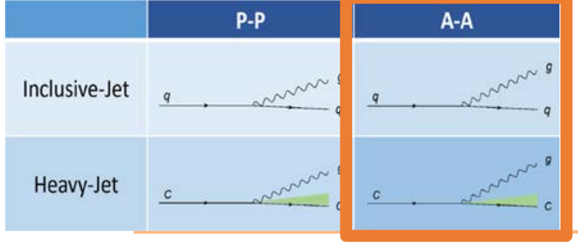
Radiative Energy Losses： Multiple Gluon Emission



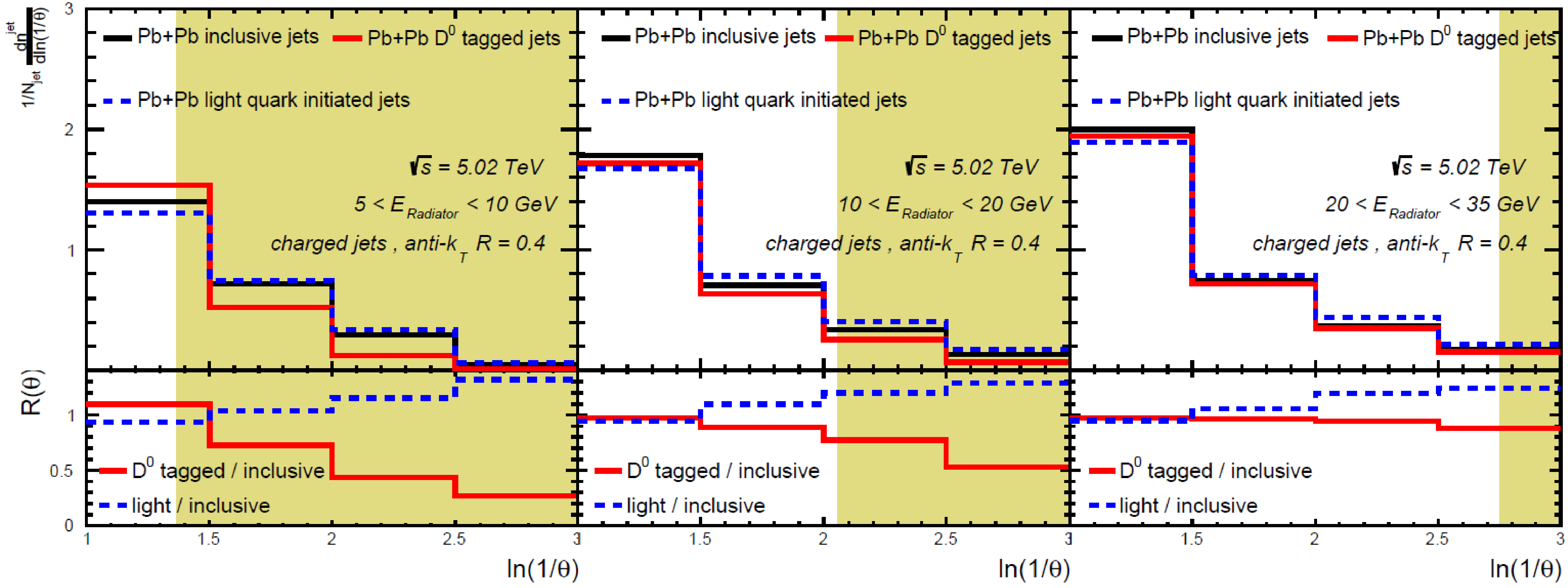
Direct observation of Dead-Cone in p+p

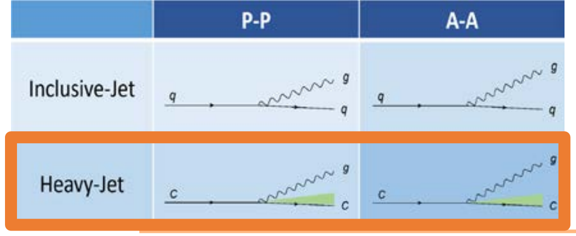


$$R(\theta) = \frac{1}{N^{D^0 jets}} \frac{dn^{D^0 jets}}{dln(1/\theta)} / \frac{1}{N^{inclusive\ jets}} \frac{dn^{inclusive\ jets}}{dln(1/\theta)} \Big|_{k_T, E_{Radiator}}$$

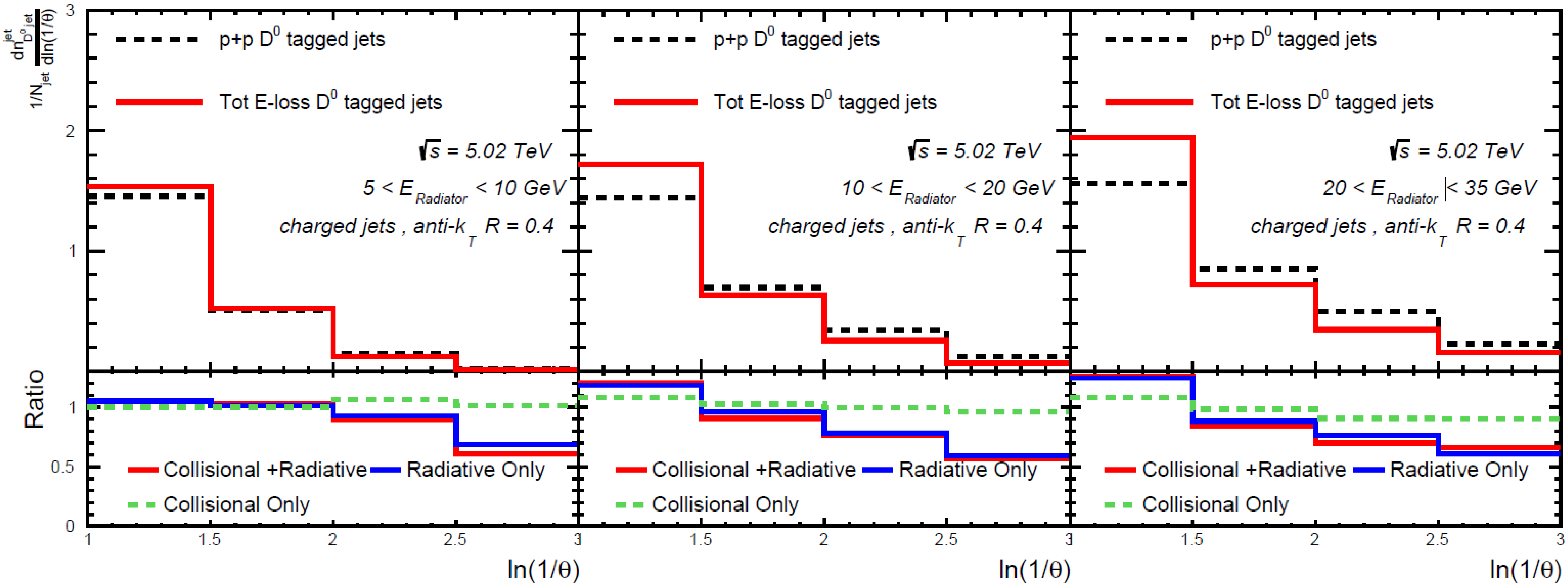


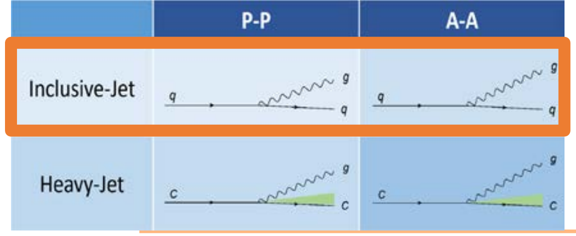
Dead-Cone exposure in A+A



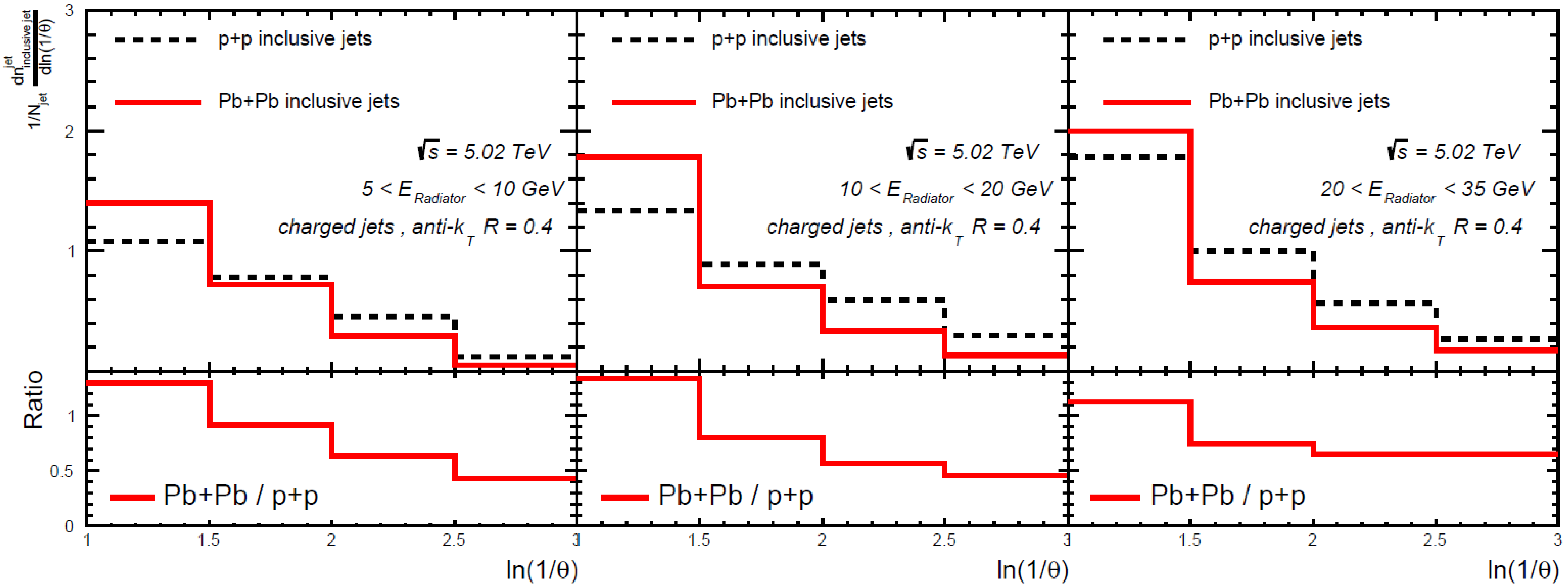


The splitting structures in A+A : I





The splitting structures in A+A: II



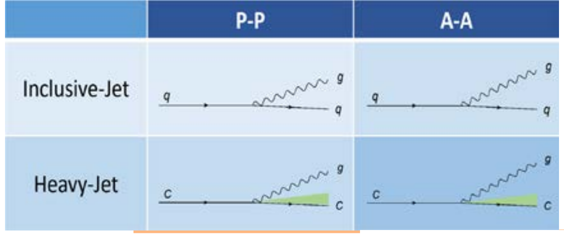
Comparison of $< \theta >$

Normalized To Number Of Jet

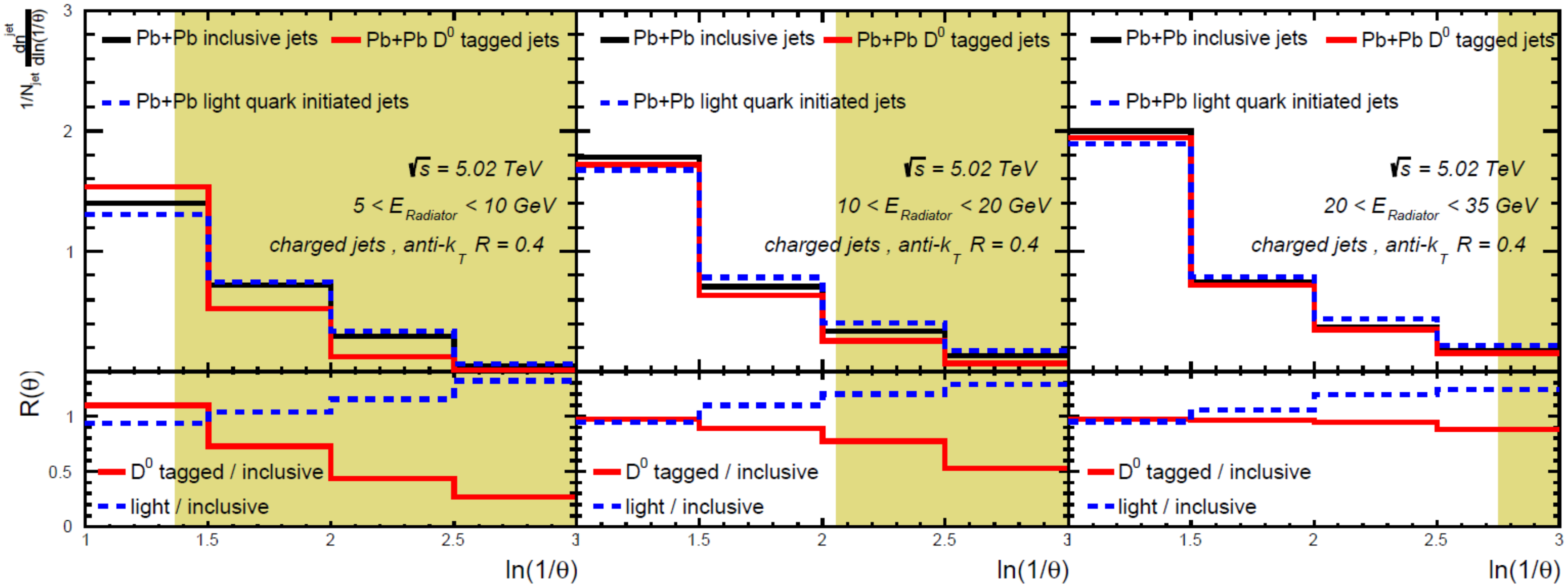
E_{Radiator}	Inclusive jets $\langle\theta\rangle_{\mathrm{jets}}$	D^0 jets $\langle\theta\rangle_{\mathrm{jets}}$	
5 – 10 GeV	0.31	0.34	pp
	0.36	0.36	AA
10 – 20 GeV	0.40	0.37	pp
	0.45	0.42	AA
20 – 35 GeV	0.47	0.42	pp
	0.49	0.47	AA

Normalized To Number Of Splitting

E_{Radiator}	Inclusive jets		D^0 jets		
	$\langle\theta\rangle_{\mathrm{spl}}$	$\mathrm{N}_{\mathrm{spl}}$	$\langle\theta\rangle_{\mathrm{spl}}$	$\mathrm{N}_{\mathrm{spl}}$	
5 – 10 GeV	0.227	1.358	0.277	1.233	pp
	0.256	1.405	0.280	1.280	AA
10 – 20 GeV	0.220	1.810	0.244	1.510	pp
	0.254	1.757	0.263	1.600	AA
20 – 35 GeV	0.232	2.040	0.232	1.822	pp
	0.249	1.977	0.251	1.860	AA



Conclusion



1. The Direct Observation of the in-medium Dead-Cone Effect still can be suggested.

2. Dead-cone effect will leading the survived splitting-angle of heavy flavor initiated splitting distributed at a larger angle; however, the possibility of such emission will be suppressed.

3. The collisional energy loss mechanism will not compromise such observation.

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Thanks for your Attention!